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(71) Applicant(s)
Linde Aktiengesellschaft

(Incorporated in the Federal Republic of Germany)

Abraham-Lincoln-Strasse 21, D-65189 Wiesbaden, Federal Republic of Germany

(72) Inventor(s)
Franz Fleckenstein
Peter Beater
Manfred Piper

(74) Agent and/or Address for Service
G F Redfern & Co
Marlborough Lodge, 14 Farncombe Road, WORTHING, West Sussex, BN11 2BT, United Kingdom

(54) Improvements in braking vehicles with hydrostatic drive

(57) During braking of a vehicle with a hydrostatic propulsion drive, an adjustable hydraulic motor (4) of the hydrostatic propulsion drive is adjusted in the direction of the greatest possible capacity and the kinetic energy of the vehicle is partly directed into a prime moved (1) and partly dissipated by pressure limiting valves (7, 8) in the closed working circuit of the hydrostatic drive. When the rotary speed of the prime mover (1) exceeds a limit during braking, the capacity setting reached by the hydraulic motor (4) is maintained, or the capacity is fixed at a defined level, until the rotary speed has dropped below the limit again. Then, the adjustment of the hydraulic motor (4) in the direction of the greatest possible capacity is continued. The capacity of the hydraulic motor (4) is set by a control pressure, and the control pressure is reduced to increase the capacity of the hydraulic motor (4) when braking. The control pressure is influenced when the rotary speed of the prime mover (1) exceeds the limit by a braking torque limiting device (B) operative according to the rotary speed of the prime mover (1). A modification (Fig 4) has a shuttle valve with two inlets in the motor control circuit. In a further modification (Fig 5), the spring side of a pressure limiting valve in the control circuit is additionally acted upon by pressure upstream of a measuring orifice.

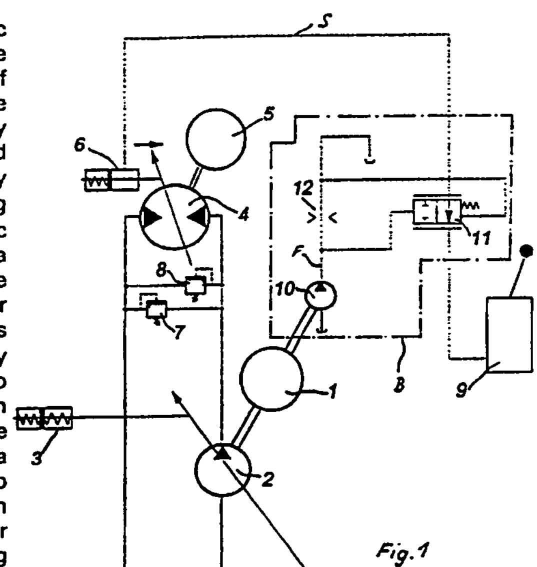

Fig.1

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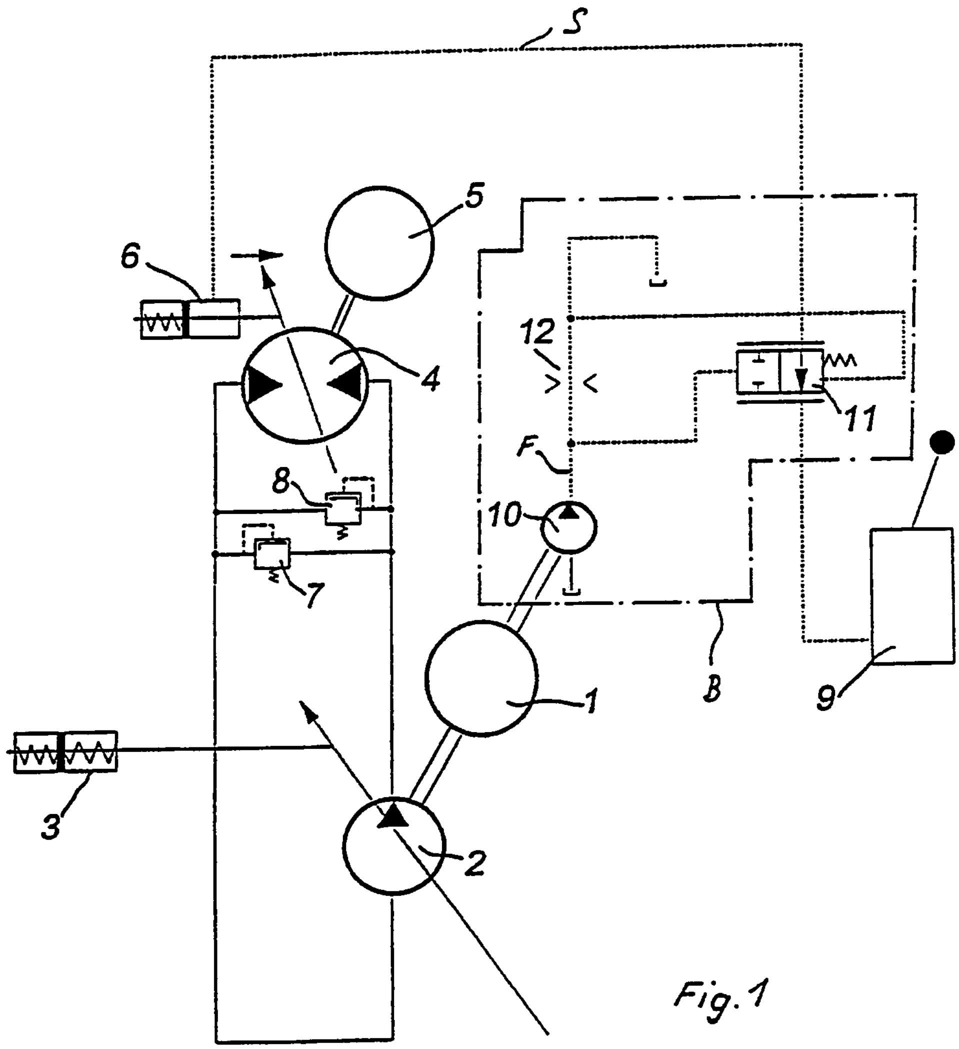

Fig. 1

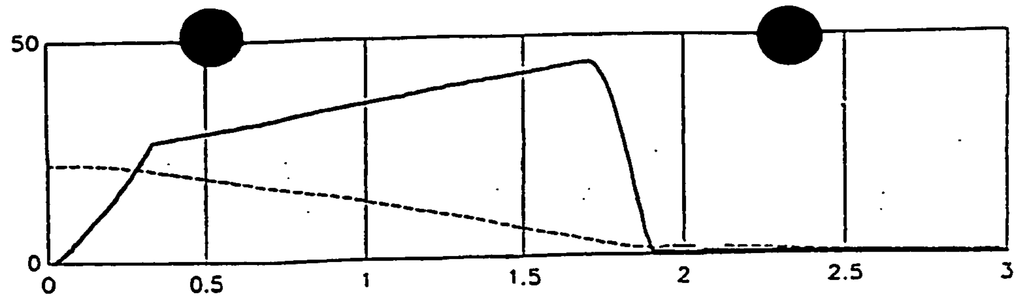

Fig. 2a

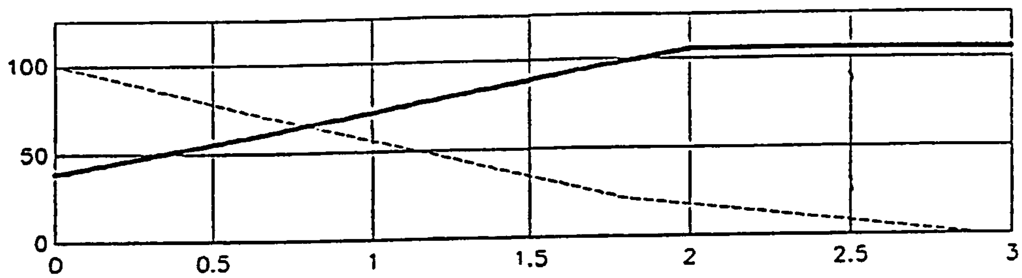

Fig. 2b

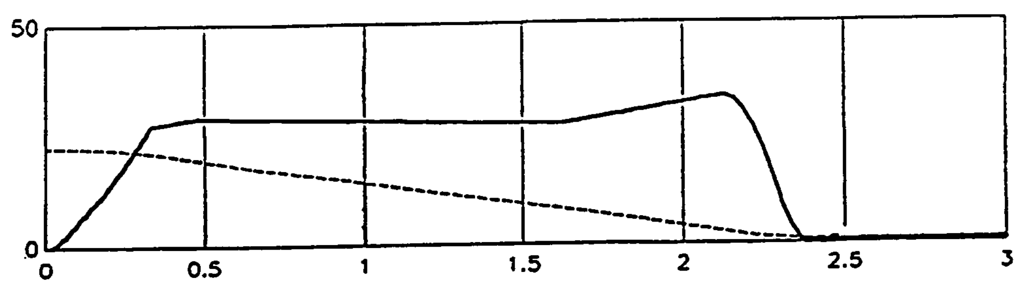

Fig. 3a

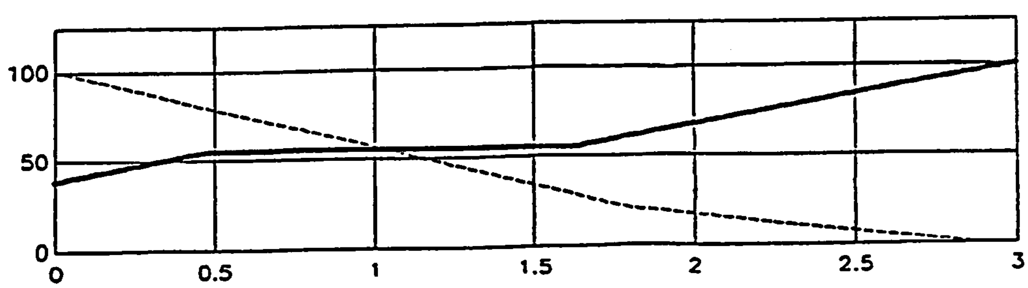

Fig. 3b

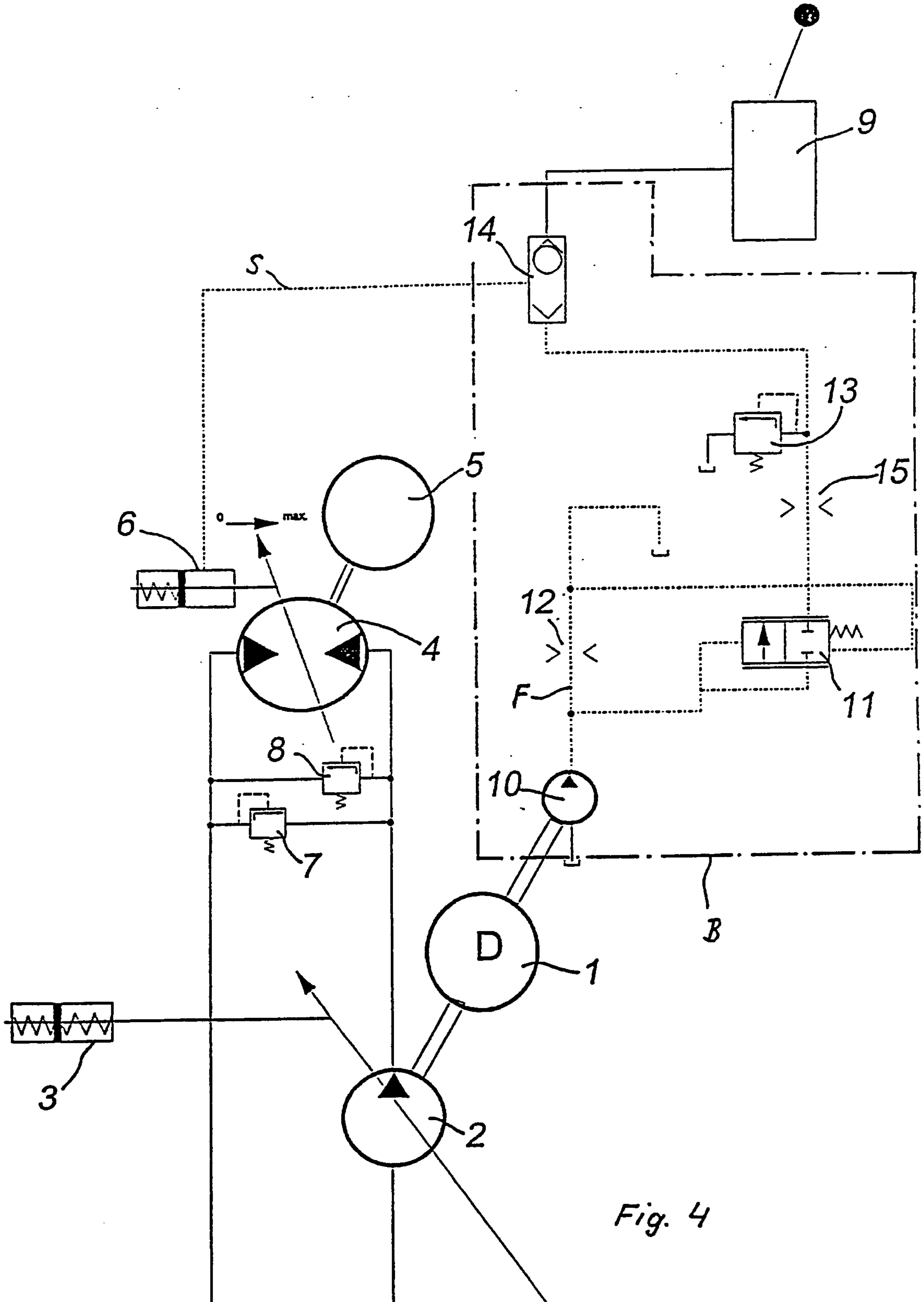

Fig. 4

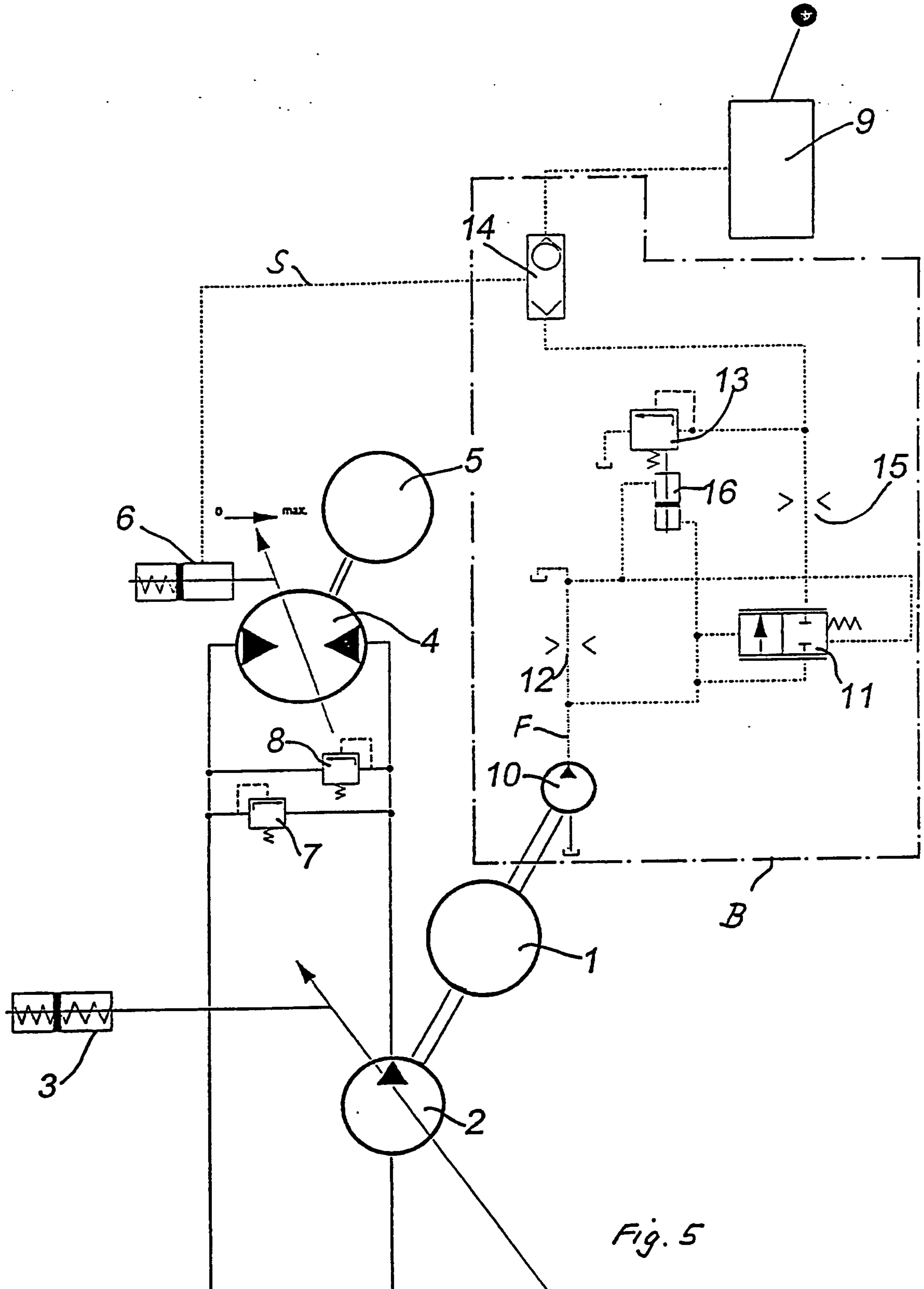

Fig. 5

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IMPROVEMENTS IN VEHICLES WITH HYDROSTATIC DRIVE

The invention relates to hydrostatic drives for vehicles, and particularly concerns a method for braking a vehicle with a hydrostatic propulsion drive in which an adjustable hydraulic motor of the hydrostatic propulsion drive is initially adjusted in the direction of the greatest possible capacity, and the kinetic energy of the vehicle is partly directed into a driving engine and partly reduced by pressure limiting valves in the hydrostatic propulsion drive. The invention also concerns a vehicle provided with a driving engine and a hydrostatic propulsion drive which includes a hydraulic pump and a hydraulic motor of variable capacity connected to it in a closed circuit, with which the kinetic energy of the vehicle during braking can partly be directed into the driving engine and partly dissipated by pressure limiting valves disposed in the hydrostatic propulsion drive, and the capacity of the hydraulic motor can be increased for braking.

Vehicles with a hydrostatic propulsion drive are well known in the art. The closed circuit hydrostatic propulsion drive has proved to be advantageous for industrial machines such as forklift trucks for example. A prime mover, such as an internal combustion engine (a diesel engine for example), drives a hydrostatic variable displacement pump whose output and intake sides are connected respectively to the hydraulic input and output of a hydraulic motor in closed circuit. On the output shaft of the hydraulic motor is connected to the driving wheels of the industrial machine, either directly or by means of a mechanical transmission.

Variants are also known in which a plurality of hydraulic motors are connected in parallel. In addition, it is also possible to use a plurality of variable displacement pumps. The direction of flow and the volumetric flow rate of the fluid are predetermined by the displacement of the variable displacement pumpvariable displacement pump, such that it is possible to drive the vehicle in either direction and at any selectable speed by adjusting the displacement of the variable displacement pump.

For heavy machines, e.g. machines with an unladen weight of more than 10 tonnes, it is customary to employ a hydraulic motor of variable capacity to provide a capability for secondary adjustment. In such a vehicle, when the vehicle pulls away from rest, the capacity of the hydraulic motor is set to the maximum and the displacement of the variable displacement pump is slowly increased starting from zero. When the highest operating pressure is reached in the hydrostatic circuit, the highest possible starting torque is operative at the hydraulic motor. The capacity of the hydraulic motor remains set at its maximum up to a speed of for example 25% of the maximum speed of the vehicle. In this drive range the speed of the vehicle is controlled exclusively by regulating the displacement of the variable displacement pump.

If the maximum displacement of the variable displacement pump is reached at 25% of the maximum speed of the vehicle, then if the capacity of the hydraulic motor is reduced, a further increase in the speed of the vehicle is produced, together with a simultaneous reduction in driving torque. The maximum driving torque is no longer required in this drive range. The smallest possible capacity of the hydraulic motor is reached at approx. 50% of the maximum speed of the vehicle. In order to further increase the speed of the vehicle to the maximum, the speed of rotation of the prime mover must be increased until the maximum speed of the vehicle is reached.

When braking, the variable displacement pump, the hydraulic motor and the driving engine are given the command to adopt the settings required for slow starting, i.e. the displacement of the variable displacement pump is adjusted in the direction of zero displacement, the capacity of the hydraulic motor is adjusted in the direction of the maximum capacity and the speed control of the prime mover is set to idle. Even if the control pressure is eliminated suddenly, a certain time elapses before the variable displacement pump and the hydraulic motor reach their final settings.

The roles are then reversed: the hydraulic motor acts as a pump and the variable displacement pump acts as a motor. As the vehicle's speed is reduced, a pressure builds up in the line between the hydraulic motor and the variable displacement pump, which drives the variable displacement pump and thus applies a torque to the prime mover tending to increase its speed. Consequently, the rotary speed of the prime mover rises. The kinetic energy of the vehicle is converted into kinetic energy of the prime mover, namely into kinetic energy of the rotating and/or oscillating masses.

During light braking, in particular from low speeds, the increase in the rotary speed of the prime mover remains within limits as the prime mover, in particular when in the form of a diesel engine, is capable of building up a braking torque and consequently can absorb energy. This results in satisfactory vehicle braking characteristics.

However, if a heavy vehicle is to be braked from high speed, the kinetic energy of the vehicle is a lot greater than the kinetic energy which the prime mover can absorb. Consequently, a further possibility is necessary to reduce the kinetic energy of the vehicle. This is achieved in that in the hydrostatic circuit fluid is directed from the high pressure to the low pressure side via one or more pressure limiting valves. Thus, the kinetic energy of the vehicle is dissipated both by increasing the rotary speed of the prime mover and by throttling at the pressure limiting valve, the major part of the kinetic energy being converted at the pressure limiting valve into heating of the fluid.

Now, it has been found that although a heavy vehicle, i.e. a fully laden working machine, can be decelerated well from fairly high speeds in the manner described, this is not true for an unladen or only lightly laden vehicle. In the latter case the result is unfavourable braking characteristics for the vehicle experiences an impermissibly high deceleration. Therefore, there is a danger that the vehicle will tip forward or even overturn, or at least the load will be thrown off.

Because of the great speed range and the great difference between the unladen and laden vehicle, with a braking method of this kind it is not possible to find a setting at which the vehicle is braked neither too heavily nor too lightly.

The underlying object of the present invention is to provide a method for braking a vehicle with a hydrostatic propulsion drive, and to provide a suitable vehicle whose braking characteristics are largely independent of the speed and the laden state of the vehicle.

According to the invention this object is achieved in that when the rotary speed of the prime mover exceeds a predetermined limit during braking, the capacity setting reached by the hydraulic motor is maintained or the capacity is fixed at a defined level until the rotary speed has dropped below the limit again, whereupon the adjustment of the hydraulic motor to increase its capacity is continued. Accordingly, the objective of the invention is to avoid excessive braking of the vehicle by exerting an influence on the capacity of the hydraulic motor, this influence being controlled in response to the rotary speed of the prime mover. Here, it is assumed that the braking torque is the product of the capacity and the pressure. Accordingly, the highest braking torque is applied when the hydraulic motor is set at the greatest possible capacity and the pressure in the hydrostatic circuit is so high that the pressure limiting valve responds. According to the invention, the pressure is left at this level while the capacity of the hydraulic motor is fixed at a defined level to reduce the braking torque. Here, in the simplest case, namely when the rotary speed of the prime mover rises normally during braking, the capacity of the hydraulic motot (now acting as a pump) is held at the value it had before braking ommenced. If the rotary speed of the prime mover rises more slowly than in the case assumed to be normal, the capacity of the hydraulic motor is reset to a lower level than the value it had before braking ommenced. If the rotary speed of the prime mover rises more rapidly than in the case assumed to be normal, the capacity is set to a higher level than the setting it had before braking ommenced. The

braking method according to the invention only becomes operative at fairly high vehicle speeds at which the kinetic energy of the vehicle is so high that the rotary speed of the prime mover rises to exceed a certain limit.

The braking method according to the invention can be achieved both hydromechanically and electrically/electronically. For example, the rotary speed of the prime mover can be detected without contact (i.e. by optical sensors detecting patterned areas of arotating part of the prime mover) and when the rotary speed exceeds the limit, the capacity of the hydraulic motor can be adjusted by an electrically actuated valve so that the capacity is held constant or reset to a defined level. In addition, intervention is also possible if a predetermined difference between the required and the actual rotary speeds of the prime mover is exceeded.

The displacement of the variable displacement pump and the capacity of the hydraulic motor and the rotary speed of the prime mover are usually controlled by a control pressure transducer in accordance with the speed required by the driver.

Here, a control pressure is produced in a control pressure transducer, the capacity of the hydraulic motor is set by the control pressure and the control pressure is reduced to increase the capacity of the hydraulic motor when braking. In a further development of the invention it is proposed that the control pressure is regulated by a braking torque limiting device operative in accordance with the rotary speed of the prime mover. Thus, although the command for zero delivery for the variable displacement pump and maximum capacity for the hydraulic motor is given by the control pressure transducer at the start of braking and the control pressure would be reduced accordingly, intervention takes place at this point and according to the invention the control pressure is initially fixed at a certain level.

With a vehicle of this type, this is advantageously achieved in that a braking torque limiting device is provided which is operative when the rotary speed of the prime mover exceeds a limit,

and which maintains the capacity of the hydraulic motor at the value it had at the start of braking until the rotary speed drops below the limit, or fixes the capacity at a defined level until the rotary speed drops below the limit.

When the hydraulic motor includes an adjusting device for setting its capacity, the adjusting device being acted upon by control pressure against a spring force to ue it towards increasing the capacity and being connected to a control pressure line connected to a control pressure transducer, it is expedient if the braking torque limiting device is designed to influence the control pressure in the control pressure line.

With a view to favourable production costs and reliable operation, it is advantageous if the braking torque limiting device includes a constant displacement pump which is driven by the prime mover, and wherein the delivery line of the constant displacement pump has disposed therein a measuring orifice, and wherein a directional control valve with a closed and an open position is connected to the control pressure transducer and disposed in the control pressure line and can be urged towards its open position by the combined force of a spring and a signal derived from the pressure downstream of the measuring orifice, and can be urged towards its closed position by a signal derived from the pressure upstream of the measuring orifice The rotary speed of the prime mover is forced up during braking, and thus the constant displacement pump delivers a greater quantity of fluid, and a greater drop in pressure occurs at the measuring orifice. This drop in pressure is a measure of the rotary speed of the prime mover so this can be used to detect when the rotary speed exceeds the limit. If the drop in pressure at the measuring orifice exceeds a certain level predetermined by the force of the spring acting at the directional control valve, the directional control valve closes. As a result, the pressure in the control pressure line between the directional control valve and the adjusting device for setting the capacity cannot be reduced any further. Thus, the capacity setting reached is maintained.

Expediently, the spring at the directional control valve is designed so that the directional control valve only responds to severe braking from speeds above a certain speed, for example 14 kilometres per hour. The increase in the capacity of the hydraulic motor is delayed until the rotary speed has dropped below the limit again.

According to another favourable variant of the invention, it is proposed that the control pressure line is connected to the output of a shuttle valve the first input of which is connected to the control pressure transducer and the second input of which is connected by means of an orifice and a pressure limiting valve disposed downstream of the orifice to the output of a directional control valve with a closed and an open position which is connected to the constant isplacement pump upstream of the measuring orifice and can be acted upon by both the force of a spring and a signal derived from the pressure downstream of the measuring orifice to urge it towards the closed position, and by a signal derived from the pressure upstream of the measuring orifice to urge it towards the open position. The shuttle valve selects the higher of the two pressures at its inputs, and transmits this to the adjusting device for setting the capacity so that an automatic distinction is made between driving (control pressure from the control pressure transducer) and braking (no control pressure from the control pressure transducer; possibly fluid from the constant displacement pump via the open directional control valve). During braking, when the directional control valve is switched to the open position with a correspondingly large difference in pressure at the measuring orifice, fluid flows out of the constant displacement pump via the directional control valve, the orifice and the shuttle valve to the adjusting device of the hydraulic motor. The pressure limiting valve sets a certain pressure while the orifice limits the flow rate of fluid flowing through the directional control valve as otherwise the entire stream of fluid delivered by the constant displacement pump would flow away through the pressure limiting valve.

In both the variants of the invention described, the directional control valve can take the form of a directional control valve throttling in intermediate positions so that the onset of the influence on the capacity is always slow.

According to one advantageous development of the second variant, it is proposed that the spring side of the pressure limiting valve can be acted upon by a signal dependent on the pressure upstream of the measuring orifice. Then, not only the pre loading force of the spring but also an additional force dependent on the rotary speed of the prime mover must be overcome to open the pressure limiting valve. As a result, the capacity is set according to the difference between the excess rotary speed and the limit rotary speed of the prime mover.

For a vehicle, in particular an industrial truck with lifting hydraulics, it is particularly favourable if the pump for the lifting hydraulics is ued as the constant displacement pump, so that the consumption for limiting the braking torque remains low.

Further advantages and details of the invention will be explained in greater detail with reference to the exemplary embodiments shown diagrammatically in the accmpanying drawings, in which:

Figure 1 shows a schematic diagram of a hydrostatic propulsion drive for a vehicle according to the invention;

Figure 2a shows a graphic illustration of a braking operation with a braking method according to the prior art;

Figure 2b shows a graphic illustration of the adjustment of the capacity of the hydraulic motor with a braking method according to prior art;

Figure 3a shows a graphic illustration of the braking operation according to the invention;

Figure 3b shows a graphic illustration of the adjustment of the capacity of the hydraulic motor with the braking method according to the invention;

Figure 4 shows a schematic diagram of a second hydrostatic propulsion drive;

Figure 5 shows a schematic diagram of a third hydrostatic propulsion drive.

Referring now to the drawings, Figure 1 shows a hydrostatic propulsion drive of a vehicle according to the invention. A prime mover 1, a diesel engine for example, drives a variable displacement pump 2 whose displacement can be adjusted by means of an adjusting device 3. The actuation of the adjusting device 3 is not shown in the Figure. The variable displacement pump 2 is connected to a hydraulic motor 4 in a closed circuit. The hydraulic motor 4 drives a driving axle or the like, possibly via a mechanical transmission. This output assembly is designated 5. The capacity of the hydraulic motor 4 can be adjusted by means of an adjusting device 6. Pressure limiting valves 7 and 8 allow fluid to flow from the high pressure to the low pressure side, or vice versa, if the highest permissible pressure is exceeded in the hydrostatic circuit. The highest permissible pressure may, for example, be set at 400 bar. The adjusting device 6 of the hydraulic motor is connected by means of a control pressure line S to a control pressure transducer 9. When a control pressure is present in the control pressure line S, this acts in the adjusting direction against the force of a spring which endeavours to set the capacity of the hydraulic motor 4 to the highest possible level. Thus, after the control pressure reaches a value which can overcome the pretension in the spring, further increases in the control pressure in line S will reduce the capacity of the hydraulic motor 4.

When the control pressure transducer 9 also supplies the adjusting device 3 of the variable displacement pump 2 with control pressure, the system is designed so that as the control pressure in line S rises, only the displacement of the variable displacement pump 2 is increased initially while the capacity of the hydraulic motor 4 remains set to the maximum due to the effect of the pretension of the spring in the adjusting device 6. Therefore, when the vehicle is

pulling away, the capacity of the hydraulic motor 4 is set to the maximum due to the force of the spring in the adjusting device 6 and a low control pressure which initially serves exclusively to adjust the displacement of the variable displacement pump 2. The displacement of the variable displacement pump 2 is increased slowly from zero by continuously increasing the control pressure. The maximum possible starting torque is operative at the hydraulic motor 4 when the highest operating pressure is reached in the hydrostatic circuit.

The capacity of the hydraulic motor 4 remains set to its maximum up to a speed of for example 25% of the maximum speed of the vehicle. In this drive range the speed of the vehicle is controlled exclusively by the displacement of the variable displacement pump 2. If its maximum displacement is reached at 25% of the maximum speed of the vehicle, further increasing the control pressure overcomes the force of the spring in the adjusting device 6 and consequently the capacity of the hydraulic motor 4 is reduced, through which the speed of the vehicle is increased further with a simultaneous reduction in driving torque. The maximum driving torque is no longer required in this drive range. The smallest possible capacity of the hydraulic motor 4 is reached at for example 50% of the maximum speed of the vehicle. In order to be able to increase the speed of the vehicle further up to the maximum, the rotary speed of the prime mover 1 is now increased until the greatest possible speed of the vehicle is reached.

When braking, the variable displacement pump, the hydraulic motor and the prime mover are given the order to adopt the positions required for slow starting, i.e. by reducing the control pressure the variable displacement pump is adjusted in the direction of zero displacement, the hydraulic motor in the direction of the maximum capacity and the prime mover to idle.

Thus, the roles are reversed: the hydraulic motor 4 becomes the pump and the variable displacement pump 2 the motor. As the speed is reduced, a pressure builds up in the line between the

hydraulic motor 4 and the variable displacement pump 2, which drives the variable displacement pump 2 and thus the prime mover 1. Consequently, the rotary speed of the prime mover 1 will rise. The kinetic energy of the vehicle is converted into kinetic energy of the prime mover 1, namely into kinetic energy of its rotating and/or oscillating masses.

During light braking, in particular from low speeds, the rise in the rotary speed of the prime mover 1 remains within limits as the prime mover 1, in particular when in the form of a diesel engine, is capable of building up a braking torque and consequently can absorb energy.

When braking from high speed, the kinetic energy of the vehicle is a lot greater than the kinetic energy which the prime mover 1 can absorb. Consequently, in the hydrostatic circuit fluid is directed from the high pressure to the low pressure side via the pressure limiting valve 7 or 8. Thus, the kinetic energy of the vehicle is dissipated both by increasing the rotary speed of the prime mover 1 and by throttling at the pressure limiting valve 7 or 8, the major part of the kinetic energy being converted at the pressure limiting valve 7 or 8. Clearly, the direction of travel of the vehicle will determine the direction of rotation of the pump 2 and motor 4, and thus will determine which is the high and which the low pressure line.

The hydrostatic circuit, in particular the adjusting characteristic of the hydraulic motor 4, is designed so that when the vehicle is fully laden and braked from high speed, satisfactory braking characteristics are guaranteed with an adequate braking torque.

However, when the vehicle is unladen or only lightly laden, this braking characteristic is unsatisfactory as the vehicle is braked too sharply.

Figure 2a shows such a braking operation in the form of a graph. Here, the time in seconds is plotted on the abscissa. The speed from 0 to 50 km/h and the braking from 0 to 50% are plotted on

the ordinate. According to the definition, the braking is the ratio between the braking torque and the static weight (force) resting on the axle or axles of the vehicle. The vehicle speed is shown by the broken line, the braking by the solid line.

Figure 2b shows the capacity of the hydraulic motor 4 over time with the solid line and the displacement of the variable displacement pump 2 with the broken line. The capacity and displacement of the hydrostatic machines are plotted in cm^3 on the ordinate.

This example is based on a vehicle with an unladen weight of 13 tonnes, which is braked from a speed of 22 km/h. However, the design braking torque is for a vehicle weight (unladen weight plus payload) of 22 tonnes.

The capacity of the hydraulic motor 4 increases linearly with time, while the displacement of the variable displacement pump 2 decreases linearly with time (Figure 2b). At the start of the braking operation, the pressure in the hydrostatic circuit initially rises to the level (400 bar for example) at which the pressure limiting valve 7 or 8 opens. The braking then increases linearly with the time as well. In this example the result is a maximum of 44%, which is unacceptably high.

According to the invention, a braking torque limiting device B is provided. In the variant shown in Figure 1 this inludes a constant displaement pump 10 which is driven by the prime mover 1. In the delivery line F of constant displaement pump 10 is disposed a measuring orifice 12. A directional control valve 11 with a closed and an open position is disposed in the control pressure line S. The directional control valve 11, which can take the form of either an open/closed valve and a directional control valve throttling in intermediate positions, is urged towards its open position by the force of a spring and by the pressure downstream of the measuring orifice 12. It is acted upon by the pressure upstream of the measuring orifice 12 to urge it in the direction of the closed position. When, during braking, the control pressure for the

adjusting device 6 of the hydraulic motor 4 is reduced by the control pressure transducer 9 and the rotary speed of the prime mover 1 rises as a result, the constant displacement pump 10 delivers a greater quantity of fluid and thus a greater drop in pressure occurs at the measuring orifice 12. As soon as the drop in pressure reaches a certain level determined by the spring acting on the directional control valve 11, the directional control valve 11 closes completely. The reduction in the control pressure in the adjusting device 6 is interrupted completely when the directional control valve 11 is completely closed. As a result, the capacity of the hydraulic motor 4 remains at the level which occurred at the time the directional control valve 11 closed.

Figures 3a and 3b are similar illustrations to Figures 2a and 2b but now account is taken of the presence of the braking torque limiting device according to the invention.

The limit rotary speed of the prime mover 1 are reached at the time t = 0.5 s so that the directional control valve 11 switches to the closed position (not shown). Consequently, the capacity of the hydraulic motor 4 stops increasing and remains at the level reached at the time the directional control valve 11 closed. Therefore, the braking hardly alters at all up to the time t = 1.6 s. At this time, the rotary speed of the prime mover 1 drops below the limit again and the directional control valve 11 opens. Therefore, the reduction in the control pressure in the control pressure line S continues and the capacity of the hydraulic motor 4 rises. As a result, now a greater braking torque is built up so that a permissible maximum level is reached with 33% braking at the time t = 2.2 s.

Figure 4 shows a second variant of the invention. Here, a shuttle valve 14 is provided, with its output connected to the control pressure line S and with its first input connected to the control pressure transducer 9. The second input of the shuttle valve 14 is connected to the delivery line F of the constant displacement pump 10 upstream of the measuring orifice 12, this line section

between the constant displacement pump 10 and the shuttle valve 14 including the directional control valve 11, a second orifice 15 and a pressure limiting valve 13. According to this variant, the directional control valve 11 is acted upon by the force of the spring and by the pressure downstream of the measuring orifice 12 to urge it in the direction of its closed position. The directional control valve 11 is urged in the direction of its open position by the pressure upstream of the measuring orifice 12. The shuttle valve 14 serves to select the higher of the pressures at its two inputs and transmits this to the adjusting device 6 to set the capacity of the hydraulic motor 4 so that a distinction is automatically made between driving (control pressure from the control pressure transducer 9) and braking (no control pressure from the control pressure transducer 9; possibly fluid from the constant displacement pump 10 through the opened directional control valve 11). When braking, when the directional control valve 11 is switched to the open position with a correspondingly large difference in pressure at the measuring orifice 12, fluid flows out of the constant displacement pump 10 via the directional control valve 11, the second orifice 15 and the shuttle valve 14 to the adjusting device 6 of the hydraulic motor 4. The pressure limiting valve 13 sets a certain pressure while the second orifice 15 limits the flow rate of fluid flowing through the directional control valve 11 as otherwise the entire stream of fluid delivered by the constant displacement pump 10 would flow away through the pressure limiting valve 13.

A further development of the variant just described is shown in Figure 5. Here, the spring side of the pressure limiting valve 13 is additionally acted upon by the pressure upstream of the measuring orifice 12. As a result, the capacity of the hydraulic motor 4 is set according to the value by which the rotary speed of the prime mover 1 exceeds the limit. The pressure made available by the pressure limiting valve 13 and transmitted to the adjusting device 6 of the hydraulic motor 4 is determined according to the difference in pressure across the measuring orifice 12 since both the force of the

spring and the force generated by a small cylinder and piston unit must be overcome to open the pressure limiting valve 13.

In an industrial truck with lifting hydraulics, a constant displacement pump 10 is usually provided as a pump for the lifting hydraulics. When the invention is applied to such a vehicle, there is no need for a measuring pump provided specifically for the braking torque limiting device, since the constant displacement pump provided as a pump for the lifting hydraulics can serve as the pump for the braking torque limiting device.

The adjustment of the capacity of the hydraulic motor 4 can be effected, as shown in the embodiment example, both directly and indirectly, i.e. pilot controlled, when the pressure predetermined by the control pressure transducer 9 or the braking torque limiting device B then forms the set value for a positional control.

CLAIMS

1. A method for braking a vehicle having a hydrostatic propulsion drive including a prime mover driving a pump supplying pressurised fluid to at least one adjustable hydraulic motor, in which the adjustable hydraulic motor of the hydrostatic propulsion drive is adjusted to increase its capacity, and the kinetic energy of the vehicle is partly directed into the prime mover and partly dissipated in pressure limiting valves in the hydrostatic propulsion drive, wherein a sensor detects the speed of revolution of the prime mover, and when the rotary speed of the prime mover exceed a predetermined limit during braking, the capacity setting reached by the hydraulic motor is maintained or the capacity is fixed at a defined level until the rotary speed have dropped below the limit again, whereupon the adjustment of the hydraulic motor to increase its capacity is continued.

2. A method according to claim 1, in which the capacity of the hydraulic motor is set by a control pressure produced in a control pressure transducer, and the control pressure is reduced to increase the capacity of the hydraulic motor when braking, wherein the control pressure is influenced by a braking torque limiting device operative according to the rotary speed of the prime mover.

3. A vehicle with a prime mover and a hydrostatic propulsion drive including a hydraulic pump and a hydraulic motor of variable capacity connected thereto in closed circuit, wherein the kinetic energy of the vehicle during braking can partly be directed into the prime mover and partly dissipated in pressure limiting valves disposed in the hydrostatic propulsion drive, and the capacity of the hydraulic motor can be increased for braking, wherein a braking torque limiting device is provided which is operative when the speed of the prime mover exceeds a predetermined value, to maintain the capacity setting reached by the hydraulic motor until the speed of the prime mover drops below the said predetermined value, or to fix the capacity of the hydraulic motor at a defined level until the speed of the prime mover drops below the said predetermined value.

4. A vehicle according to claim 3, in which the hydraulic motor includes an adjusting device for setting its capacity, the adjusting device being acted upon by control pressure against a spring force operative to increase the capacity of the hydraulic motor, and the adjusting device being connected to a control pressure line connected to a control pressure transducer, wherein the braking torque limiting device is designed to influence the control pressure in the control pressure line.

5. A vehicle according to claim 4, wherein the braking torque limiting device includes a constant displacement pump which is driven by the prime mover, and wherein the delivery line of the constant displacement pump has disposed therein a measuring orifice, and wherein a directional control valve with a closed and an open position is connected to the control pressure transducer and disposed in the control pressure line and can be urged towards its open position by the combined force of a spring and a signal derived from the pressure downstream of the measuring orifice, and can be urged towards its closed position by a signal derived from the pressure upstream of the measuring orifice.

6. A vehicle according to claim 4, wherein the control pressure line is connected to the output of a shuttle valve having two inputs, the first input being connected to the control pressure transducer and the second input being connected, via an orifice and a pressure limiting valve disposed downstream of the orifice, to the output of a directional control valve having a closed and an open position which is connected to the constant displacement pump upstream of the measuring orifice, the directional control valve being urged towards its closed position by the combined force of a spring and a signal derived from the pressure downstream of the measuring orifice, and towards its open position by a signal derived from the pressure upstream of the measuring orifice.

7. A vehicle according to claim 5 or 6, wherein the directionalcontrol valve takes the form of a directionalcontrol valve capable of throttling in intermediate positions.

8. A vehicle according to claim 7 as dependant on claim 6, wherein the spring side of the pressure limiting valve can be acted upon by a signal dependent on the pressure upstream of the measuring orifice.

9. A vehicle according to one of claims 5 to 8, in particular an industrial truck with lifting hydraulics operated by a constant displacement pump, wherein the pump provided for the lifting hydraulics is the constant displacement pump of the braking torque limiting device.

10. A vehicle substantially as described herein with reference to Figures 1, 3a,3b, 4 or 5 of the acompanying drawings.

11. A method for braking a vehicle having a hydrostatic propulsion drive, substantially as described herein.

Patents Act 1977
Examiner's report to th[illegible]mptroller under Section 17
(The Search report)

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Search Examiner
A BURROWS

Date of completion of Search
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Documents considered relevant following a search in respect of Claims :-
1-11

Relevant Technical Fields

(i) UK Cl (Ed.M) F2W (W3, W4, W5)

(ii) Int Cl (Ed.5) F16H 61/42, 61/46

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii) ONLINE DATABASES: WPI

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages	Relevant to claim(s)
A	GB 1599553 (SAVER GETRIEBE)	
A	EP 0180916 A1 (SHIMADZU)	

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